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Method and apparatus for automated detection and checking of geometrical and/or textural features of an object

The invention concerns a method as set forth in the classifying portion of claim 1 and an apparatus for carrying out the method.

The invention lies in the technical field of optically checking various views of an object, which is to be carried into effect for example in the process of circuit production and assembly.

In regard to circuit production and assembly it is particularly necessary to check the prints on the top side of circuits in terms of their existence there and their quality (discernibility) in order to prevent confusions from occurring. In addition it is necessary to measure the connections ('terminal or connection legs') which are disposed at the underside of the circuits, to ascertain whether they all lie within a predetermined tolerance range in one plane so that for example in a subsequent soldering process they can be simultaneously and reliably involved with the solder. That checking operation or ascertaining the deviation of the ends of the terminal legs from a flat contact surface is referred to as coplanarity checking. This coplanarity checking operation can be effected from a side view on to the rows of terminal legs at the sides of the circuit. Besides the above-mentioned print quality assessment and the coplanarity checking, the housing bottom clearance of a component and pitch, twist or skew, width, position, length deviation and contact point of the terminal connections are measured in the context of a so-called 'lead and mark inspection'.

Automatic reading of plain text on products is state of the art; see for example R Koy-Oberthür: 'Übersicht industrieller Anwendungen der Klarschrift- und Barcode-identifikation', Symposium: Aktuelle Entwicklungen und Realisierungen der Bildverarbietung, 11th and 12th September 1997, Aachen, Ministerium für Wirtschaft, Mittelstand und Technologie des Landes Nordrhein-Westfalen. The aim pursued by that procedure is to recognise the individual symbols contained in the script, but not to derive an assessing measurement in terms of the readability afforded in any way thereby. It is precisely this however that is necessary and appropriate for such situations if the content of the printing is known per se but its potential readability has to be guaranteed, for example for liability and monitoring situations.

The lecture by T Schroeter: 'Einsatz der Bildverarbeitung zur Druckvollständigkeitskontrolle' at the same Symposium described a method which detects the completeness of printing, that is to say checks it for missing characters. That method makes use of the so-called histogram information. The method described herein assesses the printed area without deriving an evaluation in terms of the readability of the identification.

It is also known to implement a coplanarity check on circuits by means of optical methods with which gap widths can be measured. In the procedure described by Qtec in 'Industrielle Bildverarbeitung/Maschine Vision', VDM, Robotik Automation, Maschinenbau Verlag GmbH, Frankfurt/Main. 1997, an image is taken from the underside of the circuit to be checked, that image permitting a view on to shadows cast by the rows of connection legs. A disadvantage in this respect is that evaluation is effected only from one image which is recorded directly from an individual side of the object to be monitored, and thus it is not possible also to implement a print quality check. The location of the shadow of a connection leg to be measured, on a base surface, is moreover influenced not only by the distance thereof from the base surface (on which the shadow is cast) but also the location of the connection leg over that base surface, and moreover the specific shape of the connection leg, from which major errors

can result. Furthermore, with this procedure, a plurality of individual light sources are required to produce an evaluatable shadow image.

The coplanarity monitoring unit SMD9000 from Trigon Adcotech uses five CCD-cameras for recording the images to be evaluated, for monitoring coplanarity, one for each side view and one for a plan view. A disadvantage in this respect is the high level of technical complication and expenditure arising out of the number of cameras required, and the fact that the individual views are not linked to each other.

In addition WO 98/04882 discloses a method of the general kind set forth for the automated detection and checking of geometrical and textural features of an IC component in side views and a plan view. In that case detection of the features is effected using a CCD-camera and a corresponding storage unit and evaluation unit for image processing and image evaluation. In that case, quality and state assessment of the object is effected by a comparison with parameters which are predetermined in respect of the individual features, wherein the partial images of the object are substantially simultaneously recorded by means of a single CCD-camera by virtue of a suitable beam-deflection device and are at least partially assembled optically at the same time to form an overall image which shows all views and in which the boundaries of the partial images can be recognised. The overall image is then separately evaluated for checking the individual features in the boundaries of the partial images. In this case the coplanarity of the legs of the IC-component is also checked. That publication however does not disclose the form in which that evaluation procedure is implemented.

Therefore the object of the present invention is to provide a method and an apparatus which make it possible at relatively low cost to detect and check in interrelated manner and reliably in relation to coplanarity structural and/or textural features of an object in a plurality of views, more especially in a plan view and in side views.

In regard to its method aspect that object is attained by a method having the features of claim 1 and in regard to its apparatus aspect by an apparatus having the features recited in claim 7.

The invention involves the technical teaching of obtaining from a single viewing position by means of suitable optical means an overall image constructed from partial images of various views of the object with a level of resolution which is sufficient for simultaneous structure and texture checking.

The partial images are substantially simultaneously recorded and at least partially brought together optically at the same time to form an overall image showing all views, in which the boundaries of the partial images can be seen, and that is evaluated in the boundaries of the partial images separately - that is to say with different evaluation means or in terms of different parameters.

In accordance with the invention firstly in the regions of the overall image which show side views on to the object, analysis of the gray value distributions is effected to ascertain locations in which parts (to be checked in terms of coplanarity) of the object come very close to a substrate. Subsequently the light quantity which passes through between the object and the substrate and which is reflected at the pixels as an intensity value is detected and, utilising the intensity values, the local light quantity pattern or configuration which characterises the width of a gap between the object and the substrate is determined. Finally the light quantity pattern or configuration can be converted into a gap width in accordance with a predetermined algorithm, utilising calibration information. The rule for conversion of an intensity pattern as between object and support is advantageously implemented on the basis of a spline approximation, the determination of rise values and calibration, in such a way that an area proportion under the spline curve determines the value of the gap width between the object and the support surface. That procedure is expedient especially for coplanarity checking of circuits or similar objects.

In a preferred embodiment all partial images are assembled optically and recorded by precisely one image-recording device, wherein in the overall image the regions of the partial images are so positioned and characterised, in particular using the storage unit and/or the evaluation

unit, in such a way that they can be associated for the evaluation procedure with the individual views.

Checking the object is made easier in many uses if in at least one additional step the scene is recorded without an object and/or with a reference object which has predetermined parameters in regard to the features, and the corresponding overall image is stored in the storage device for comparison and calibration purposes.

In a region of the overall image (which for example shows the plan view of a circuit), for the purposes of detecting a texture and especially for checking the readability of a characterisation or identification, preferably by means of image processing, using convolution filters, areas with severe local intensity differences are emphasised, detected and quantified in terms of their dimensions, the result of the quantification operation in the above-mentioned areas is compared to given values and subsequently quality information is derived in respect of the texture or identification.

In the apparatus according to the invention there is provided a flat support surface for the object, and the beam-deflection means are substantially arranged in the plane of the support surface in such a way that there is a view parallel to the support surface, permitting checking of the coplanarity of a plurality of parts of the object, which are towards the support surface.

The apparatus according to the invention preferably includes a single image-recording device, relative to which the object is positioned in such a way that it fills only a part of its field of view, wherein arranged in remaining parts of the field of view are beam-deflection devices which produce images of side views of the object on the image-recording device.

The beam-deflection devices are so positioned that they respectively produce an image of a given view of the object, but do not influence the other views (especially the plan view on to the object).

The means for beam deflection have in particular prisms or mirrors which are fixed or displaceable and which can have surfaces which are optionally curved for specific uses. In addition or alternatively thereto they may have a light guide arrangement (one or more glass fiber bundles).

Associated with at least one of the beam-deflection devices are means for altering the imaging scale of at least one partial image with respect to at least one other partial image, in particular a lens arrangement.

Furthermore the apparatus preferably includes - especially for coplanarity checking procedures - a lighting device which in particular has a light diffuser device for producing a regular light flux under the object, which is arranged behind (from the point of view of the beam-deflection device) projecting parts of the object.

In that case the light diffuser device can preferably be interrupted in such a way that the free spaces permit a view on to the underside of the object.

For recording a plan view, in a preferred feature a further lighting device which is suitable specifically for evaluating the recognisability of a surface texture is then arranged over the object.

A preferred apparatus is one in which the image-recording device and the storage and evaluation unit are integrated in a structural unit. That can be for example a so-called 'smart camera', as however is hitherto not used for lead and mark inspection. The advantages of using an integrated component are that on the one hand it is easily obtainable and on the other hand it can be easily configured for use in the context of the procedures described hereinbefore.

Advantageous embodiments of the invention are also set forth in the appendant claims, and the description hereinafter with reference to the accompanying drawings in which:

Figure 1 shows a diagrammatic simplified view of the overall structure of an embodiment of an apparatus according to the invention,

Figure 2 shows an overall image of an example of an object to be checked, with a plan view and side views recorded from a viewing position,

Figure 3 is a view of part of a further embodiment with advantageously arranged lighting devices for producing top light and relative transillumination,

Figure 4 shows a view of the intensity profile of a gap section between a support and a projecting part of an object, which is towards same,

Figure 5 shows a side view and a view from below of a component with L-shaped connections, and a side view and a view from below of a component with J-shaped connections.

Figure 1 is a diagrammatic view showing the principle of the overall structure of an apparatus for checking features, which can be recognised in side views and a plan view, of an object 1, from a single viewing position. The apparatus includes a CCD-camera 2 as an image-recording device, with an objective lens 2a which has a field of view 3, a support surface 4, prisms 5 for beam deflection purposes and lenses 6 for beam formation in respect of the deflected radiation, as well as an image evaluation and storage unit 7. A lighting device is not shown; the apparatus by way of example accordingly operates with diffuse ambient light.

The camera 2 records an overall image of the object 1, which is composed of a plurality of partial images of various views of the object. The light which is reflected from the top side 1a of the object and which passes directly into the objective lens 2a produces a partial image of the plan view, and the light which is reflected from the side surfaces 1b and which is deflected by the prisms 5 into the objective lens of the camera produces partial images corresponding to the side views. The lenses 6 produce a change in the imaging scale or the detailing of the recorded image in the parts of the beam path which are influenced by the lenses, that is to say in the partial images of the side views.

The camera 2 transmits the overall image in the form of an electrical signal pattern to the image evaluation and storage device 7 (not described in greater detail herein) which for example can be embodied by a personal computer. The image evaluation and storage unit 7 determines the boundaries and demarcation of the partial images and, using image processing and image evaluation methods which are known per se but which are specifically adapted to the features to be checked in the partial

images, extracts relevant items of information and parameters from the partial images, and prepares them for comparative evaluation.

Figure 2 shows a typical overall image 11 of a circuit in the field of view 10 of the camera, the image having been recorded by the camera 2 in the apparatus shown in Figure 1 and stored in the image evaluation and storage unit 7. The overall image 10 comprises five partial images, more specifically the partial image 11a of the plan view and the partial images 11b through 11e of the side views. Printing 12 on the top side of the circuit stands out clearly in its intensity from the intensity of the ambient light. The images of the side views are formatively influenced by superposition structures 13 which include elements which are caused by gaps of different widths between the legs of the circuit 1 and the support 4. The superposition structures are evaluated by means of special image processing methods as already referred to hereinbefore and used for a checking procedure in respect of coplanarity of the circuit connections.

Figure 3 shows a detail of a modified embodiment of the arrangement shown in Figure 1, in which, in addition to the components illustrated therein, there are provided two lighting devices 8a, 8b for producing top light on the surface of the object 1 and for producing transmission light for the side views of the legs 1.1 of the circuit 1, the transmission light being rendered diffuse by a light diffuser device 9.

Figure 4 shows a spline curve S for the variation in intensity in the pixels of the digitised partial image of a side view for one of the gaps between a leg and the support. The area A_S under the spline curve S, defined by the rise points X_0 and X_1, is used in the context of a specific image evaluation procedure for the side view partial image for computation of the gap width as a coplanarity parameter.

Figure 5 denotes the parameters checked in the context of a so-called lead and mark inspection, by reference to the side view 1b of an object 1 and by reference to the underneath view 1c thereof. The object shown at the left in Figure 5 has L-shaped connections while the object shown at the right in Figure 5 has J-shaped connections. The parameters to be checked are the coplanarity CP, the housing bottom clearance ST, the

pitch PI, the twist or skew SK, the connection or lead width LW, the length LS, the connection or lead position LP, the length deviation LED, the connection dimensions TD, the contact points or the footprint FP and the housing height (not identified).